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SPRINGFIELD ARMORY

RESEARCH AND DEVELOPMENT

TECHNICAL REPORT

PROJECT TITLE: Basic Studies in Ordnance Engineering

PROJECT NO.: TB1-0004

REPORT TITLE: Periodic Reverse in Chromium Plating

ITEM: Chromium Plating **DATE:** 8 November 1957 **SA-TR16-1113**

FORM NO. ORDBD-719
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SPRINGFIELD, MASSACHUSETTS

REPORT
SA-TR16-1113

ABSTRACT

AD_____Accession No._____

Springfield Armory, Springfield, Mass., PERIODIC REVERSE IN CHROMIUM PLATING, by R.E. Bessey, Tech Rpt SA-TR16-1113, 8 Nov 57, 26 pp incl illus, Ord Proj TB1-0004, DA Proj 572-01-004, Contract DA 19-059-504-ORD-2548.

Unclassified report

Preliminary investigation was conducted to determine the effect of periodic reversal of current in chromium plating upon the corrosion resistance of chromium plated steel.

Corrosion resistance of chromium plated WD1045 steel was, in some instances, greatly improved by the use of periodic reversal of current during plating. Improvement was dependent upon preplating surface treatment. Corrosion resistance of chromium plated F81020 steel was not improved when periodic reversal of current was used during plating.

The use of periodic reverse in chromium plating can modify the structure and mechanical properties of the plate. An investigation should be made to determine optimum method of surface preparation.

UNCLASSIFIED

1. Plating, Chromium
2. Chromium Plating

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REPORT
SA-TR16-1113

8 November 1957

SPRINGFIELD ARMORY

RESEARCH AND DEVELOPMENT DIVISION

Periodic Reverse in Chromium Plating

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PROJECT NO: TB1-0004

PROJECT TITLE: Basic Studies in Ordnance Engineering

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Associated Engineers, Inc.

Contract DA-19-059-504-ORD-2548

REPORT
SA-TR16-1113

SUBJECT

Periodic Reverse in Chromium Plating.

REFERENCE

OOR Project No. N-15E, Springfield Armory File 121.24/908.

OBJECT

To conduct a preliminary investigation of the effect of periodic reversal of current in chromium plating upon the corrosion resistance of chromium plated steel.

SUMMARY

1. Panels of WD 1045 steel and rods of FS 1020 steel were chromium plated with and without periodic reversal of the current. The panels and rods were tested for corrosion resistance in the salt spray after plating. The hardness of the plate was also determined, and cross-sections of the plate were examined with a microscope.

2. The corrosion resistance of chromium plated WD 1045 steel was, in some cases, greatly improved by the use of periodic reversal of current during plating. The improvement was dependent upon the preplating surface treatment.

3. The corrosion resistance of chromium plated FS 1020 steel was not improved by having used periodic reversal of current during plating.

4. The use of periodic reverse in chromium plating can modify the structure and mechanical properties of the plate. Bend tests and microscopic examination indicate that the adhesion of the deposited plate was satisfactory when periodic reversal had been used.

SPRINGFIELD ARMORY

RESEARCH AND DEVELOPMENT DIVISION

TECHNICAL REPORT SA-TR16-1113

REBessey/mwp/rd/5185
8 November 1957

1. INTRODUCTION:

a. Chromium plate as ordinarily deposited contains a crack system which is detrimental to the corrosion resistance of chromium plated steel. When chromium is made anodic in the plating solution, the dissolution rate, in the plate, is more rapid in the cracks than elsewhere in the plate. This fact is taken advantage of to produce what is known as porous chromium which has the property of retaining oil.

b. Because of the good micro-throwing power of chromium plating, it was believed possible to anodic etch the plate first in order to attack selectively the cracks in the plate and then to deposit a layer of chromium, part of which would fill the crack system. It is thought that this process, if continued, would result in a plate with less porosity than ordinarily deposited plate.

c. Accordingly, it was decided to determine whether the use of periodic reversal of the current in chromium plating would result in improved corrosion resistance of the chromium plated steel.

d. Ordinarily, when chromium is to be plated on a previously chromium plated surface, the use of special techniques is necessary to prepare the surface because of the oxide layer present. It was, therefore, further necessary to check the adhesion of the individual "layers" of plate deposited when periodic reversal of current had been used.

2. MATERIALS AND PROCEDURE:

a. WD 1045 Steel.

(1) Panels of WD 1045 steel, 1-1/4" x 3-1/8" x .078", were chromium plated either by conventional plating procedures or by using periodic reversal of the current. The periodic reverse cycle used was five seconds reverse every three minutes. Reversal of the direction of current flow was accomplished by means of a manually operated reversing switch. All plating was done at 131°F. in a conventional plating solution consisting of 250 grams of chromium trioxide per liter and 2.5 grams of sulfuric acid per liter. The panels were prepared for plating by the various procedures listed in Table I, Appendix A. Several panels were electropolished in a sulfuric-phosphoric acid solution before cleaning.

(2) The plated panels were corrosion tested in the salt spray in accordance with Federal Specification QQ-M-151. All specimens were inclined at an angle of 45 degrees from the vertical.

(3) The Knoop hardness values of the two types of plate were determined on cross-sections from panels No. 171 (periodic reverse) and No. 148 (standard). A photomicrograph was taken of the unetched chromium plate.

b. FS 1020 Steel.

(1) Rods of FS 1020 steel, one-half inch in diameter, were chromium plated either by conventional procedures or by using periodic reversal of the current. The cycle for periodic reverse was five seconds reverse every three minutes. The surfaces of the rods were prepared for plating in accordance with procedure No. 7, Table I, Appendix A. After plating, the rods were tested for corrosion resistance in the salt spray.

2. MATERIALS AND PROCEDURE: (Contd.)

b. FS 1020 Steel. (Contd.)

(2) Rods of FS 1020 steel were also plated at current densities of eight, sixteen, and thirty-two amperes per square inch. These rods, before plating, were cleaned in accordance with procedure No. 1, Table 1, Appendix A, excepting that steps 10 and 11 were done before steps 5 and 8. A relay-operated periodic reverse unit was used in the plating of the rods. The periodic reverse cycle was fifteen seconds plate and three-fourths second reverse. These rods were also tested for corrosion resistance in the salt spray.

(3) Cross-sections were cut from rods No. 22 (standard) and No. 23 (periodic reverse), mounted in lucite, and prepared for examination. Knoop hardness values were obtained. Photomicrographs were taken of the chromium plate both before etching and after etching in one to one hydrochloric acid solution.

3. RESULTS:

a. WD 1045 Steel.

(1) The results of the salt spray corrosion tests of the WD 1045 steel plated with chromium by standard procedures and by using periodic reversal of the current are listed in Table II, Appendix A. A photograph of representative panels after completion of the salt spray tests is shown in Figure 1, Appendix B. Figure 2, Appendix B, shows the appearance of chromium plated panels with first, medium, and heavy rust. The terms "medium" and "heavy rust" are relative and are best described by the photographic view.

3. RESULTS: (Contd.)

a. WD 1045 Steel. (Contd.)

(2) In general, the time to the first appearance of rust for panels plated with periodic reverse was similar to the time for the panels plated without the use of periodic reverse. Panels which were pretreated by procedures No. 3 or No. 5, Table I, Appendix A, and plated using periodic reverse showed no improvement in corrosion resistance, but panels pretreated by the remaining procedures and plated using periodic reverse showed less extensive corrosion than panels similarly pretreated but plated by the standard procedure.

(3) The adhesion of the plates was checked by bend tests on several panels. It can be seen by examining the bent panels shown in Figure 1, Appendix B, that the adhesion for panels plated using periodic reverse is similar to the adhesion for panels plated without using periodic reverse.

(4) The hardness values of the plate on panels No. 148 (standard) and No. 171 (periodic reverse) were identical, 831 Knoop for 200 gram load. The cross-sections of the two types of plate appeared identical when viewed through a microscope at a magnification of 1000 X. There was no indication of lamination of the plate on panel No. 171. A photomicrograph of these plates is shown as Figure 1, Appendix C. After etching, the appearances of the plates were similar except for some indication of lamination on the edge (high current density area) of panel No. 171.

3. RESULTS: (Contd.)

b. FS1020 Steel.

(1) The results of the salt spray corrosion test of the FS 1020 steel rods plated with chromium either by standard procedures or by the use of periodic reversal of current are listed in Table III, Appendix A. In no case was there any improvement in the salt spray resistance of the rods plated with periodic reversal of current.

(2) A photomicrograph of the plate deposited at a current density of eight amperes per square inch by the standard procedure and using periodic reverse is shown as Figure 2, Appendix C. The plate deposited when periodic reverse was used appears to be sounder than that deposited by the standard procedure. What appear to be voids in the standard plate were caused by the removal of small bits of chromium during the preparation for examination. On the right side of the photograph there is a large piece missing from the plate deposited with periodic reverse. This plate was removed during the preliminary grinding of the specimen. There is also a macro crack through the plate deposited with periodic reverse. There are several cracks of the same type around the circumference of the rod. These cracks appear to be the cause of the poor corrosion resistance of the plated specimens.

(3) The heavy, dark lines between the plate and the steel are shadows caused by the steel having been removed faster than the chromium during the polishing operation.

3. RESULTS: (Contd.)

b. FS 1020 Steel. (Contd.)

(4) Figure 3, Appendix C, shows photomicrographs (250 X) of the same plates as are shown in Figure 2, Appendix C. The specimens were mounted separately and prepared for examination by grinding, abrading with emery, and polishing with aluminum oxide. Again, there appear to be voids in the standard plate. The pattern is different, however, thus providing additional evidence that the voids are actually caused by particles removed during processing. The photomicrographs of the etched specimens of standard plate show the crack pattern characteristic of chromium plate applied in the ordinary manner. There is no crack pattern visible in the etched specimens of plate deposited when periodic current reverse was used. In addition, the acid attack on the latter plate was more uniform, indicating the presence of a more homogeneous structure.

(5) Knoop hardness values for the plate deposited at a current density of eight amperes per square inch either with or without periodic reverse are listed in Table IV, Appendix A. The Knoop hardness value of the standard plate could not be taken with a load greater than 200 grams because of cracking of the plate. The Knoop hardness value for the plate deposited with periodic reverse was about 100 points lower than the standard and independent of the applied load within the limits tested.

4. DISCUSSION:

a. Although, in many cases, the use of periodic reverse greatly improved the corrosion resistance of chromium plated WD 1045 steel panels, the improvement in corrosion resistance was dependent upon the preplating procedure. The corrosion resistance of chromium plated FS 1020 steel was not improved by the use of periodic reverse, although the preplating procedure used was similar to that for WD 1045 steel for which improved corrosion resistance was obtained.

4. DISCUSSION: (Contd.)

b. The mechanism by which improved corrosion resistance was obtained is unknown. It does not appear to be that suggested in the Introduction whereby the improvement would be expected to be independent of the preplating treatment of the steel.

c. It is of interest to note that the plate deposited with periodic reversal of current (three-fourths second reverse, fifteen seconds plate) at a current density of eight amperes per square inch has a structure different from the plate deposited by the standard procedure at the same current density. The crack pattern was eliminated, but there was no increase in corrosion resistance apparently because of the macro cracks extending through the plate.

d. The plate deposited with periodic reversal of current was duller than the standard plate. Hardness values for standard plate and hardness values for plate deposited using a periodic reverse cycle of five seconds reverse every three minutes were identical. When a reverse cycle of three-fourths second reverse, fifteen seconds plate was used, the hardness value obtained was lower than that for standard plate. These data indicate that it is possible to alter to some extent the mechanical properties of chromium plate by the use of periodic reverse.

e. Indications of some ductility at the slow rate of loading (0.1 mm/min.) used in the Knoop hardness tests are shown by the ability of plate deposited with periodic current reversal to support a greater load without cracking than the standard plate and by the deformation visible in the photomicrograph, Figure 2, Appendix C. There was, however, no evidence of ductility in bend tests.

5. CONCLUSIONS:

a. The corrosion resistance of chromium plated steel can, under certain conditions, be improved by the use of periodic reversal of current during plating. As a result of this preliminary investigation, it appears that the improvement is dependent both upon the surface preparation before plating and upon the type of steel.

b. The use of periodic reverse during plating can modify the structure and mechanical properties of the chromium plate.

6. RECOMMENDATIONS:

a. An investigation should be made to determine the optimum method of surface preparation to be used prior to plating with periodic reversal of current. The factors responsible for improved corrosion resistance under certain conditions should be evaluated.

b. The effect of the type of steel upon results obtained should also be evaluated.

c. The effect of other periodic reverse cycles should be investigated.

d. The mechanism of the process should be investigated.

REPORT
SA-TR16-1113

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REPORT
SA-TR16-1113

APPENDICES

APPENDIX A - Tables

APPENDIX B - Photographs

APPENDIX C - Photomicrographs

TABLES

TABLE I

Preplating Procedure for WD 1045 Steel Panels

No.	Operation	Procedure No.	Sequence of Procedure 1	2	3	4	5	6	7
1.	Degrease with acetone or trichlorethylene.		1	1	1	1	1	1	1
2.	Abrade with emery paper.					2		2	2
3.	Soak and scrub with fiber brush in alkali cleaner.			3	3				
4.	Cold water rinse.			4	4				
5.	Scrub with pumice on copper brush in 1-1 HCl.		5					5	
6.	Scrub with pumice on steel wool in 1-1 HCl.			6					
7.	Scrub with pumice on fiber brush in 1-1 HCl.					7			
8.	Cold water rinse.		8	8		8		8	
9.	Grit blast.						9		
10.	Soak and scrub with fiber brush in alkali cleaner.		10				10	10	
11.	Cold water rinse.		11				11	11	
12.	Cathode clean (1 min.) in commercial electrolytic alkali cleaner.								12
13.	Cold water rinse.								13
14.	Dip in 1-1 HCl until gassing is uniform.		14	14	14		14		14
15.	Cold water rinse.		15	15	15		15		15
16.	Apply immersion coating of copper in $CuSO_4$-H_2SO_4 solution.							16	
17.	Copper strike for 30 seconds in conventional cyanide solution.								17
18.	Anodic etch for five minutes in plating solution.		18	18	18	18	18	18	18

TABLE II

Results of Salt Spray Corrosion Tests on Chromium Plated WD 1045 Steel Panels

Panel No.	Electro-polished	Cleaning Procedure	Current Density (a.s.i.)	Plate Thickness (in.)		Hours in Salt Spray			Total Hours in Salt Spray
				Standard	Periodic Reverse	First Rust	Medium Rust	Heavy Rust	
150	x	1	2.7		.0014	21	---	---	114
180	x	1	2.7		.0011	23	---	---	114
149	x	1	2	.001		4	25	27-92	92
181	x	1	2	.001		4	25	27-92	92
120	x	1	2.7	.001		5	9-15	28-45	101
187	x	1	2.7	.0009		5	9-15	28-45	101
118	x	1	2.7		.0008	1	45-53	53-69	101
162	x	1	2.7		.0009	2	28-45	53-69	101
144	x	2	2.7		.0009	3-5	---	---	83
151	x	2	2.7		.0009	3-5	---	---	83
152	x	2	2	.0009		1-2	8-24	8-24	80
153	x	2	2	.0009		1-2	5	8	80
155	x	2	2	.0015		3-4	4	6	23
156	x	2	2	.0019		4	7	7-23	23
157	x	2	2		.0011	5	---	---	31
158	x	2	2		.001	6	---	---	31

TABLE II (Contd.)

Results of Salt Spray Corrosion Tests on Chromium Plated WD 1045 Steel Panels (Contd.)

Panel No.	Electro-polished	Cleaning Procedure	Current Density (a.s.i.)	Plate Thickness (in.)		Hours in Salt Spray			Total Hours in Salt Spray
				Standard	Periodic Reverse	First Rust	Medium Rust	Heavy Rust	
167	x	3	3	.001		1	2	3	115
168	x	3	3	.001		1	3	4	115
169	x	3	3	.0011		1	2	3	115
121	x	3	3		.0008	1	2	6	115
159	x	3	3		.001	1	2	6	115
161	x	3	3		.0009	1	2	6	115
166	x	3	2	.0008		1	3	5-6	115
188	x	3	2	.0009		1	3	5-6	115
182	x	3	2	.0008		1	3	5-6	115
134	x	3	2		.0005	1	6-9	6-9	115
146	x	3	2		.0005	1	2	6-9	115
195	x	3	2		.0004	1	2	4-6	115
170	x	4	2.7		.001	2	105-113	---	129
171	x	4	2.7		.001	2	105-113	---	129
147	x	4	2.7	.001		1	9-11	35	129
148	x	4	2.7	.0011		7-8	14-19	35	129

TABLE II (Contd.)

Results of Salt Spray Corrosion Tests on Chromium Plated WD 1045 Steel Panels (Contd.)

Panel No.	Electro-polished	Cleaning Procedure	Current Density (a.s.i.)	Plate Thickness (in.)		Hours in Salt Spray			Total Hours in Salt Spray
				Standard	Periodic Reverse	First Rust	Medium Rust	Heavy Rust	
140		5	2.7	.0012		2	5	11	97
141		5	2.7	.0011		2	5	11	97
174		5	2.7		.001	1	6	22	97
201		5	2.7		.0008	1	6	22	97
103		5	2.7	.0013		2	15-23	36-53	101
105		5	2.7	.0014		3-4	15-23	36-53	101
107		5	2.7		.0011	2	61-77	77-85	101
108		5	2.7		.0008	1	15-23	36-53	101
116		6	2.7	.001		13	21-38	38-46	100
185		6	2.7	.001		11	21-38	38-46	100
136		6	2.7		.0009	9-11	---	---	100
163		6	2.7		.0008	3	---	---	100
106		7	2.7	.001		8-10	14-16	16-32	104
164		7	2.7	.0011		8-10	14-16	16-32	104
102		7	2.7		.001	3-5	---	---	104
186		7	2.7		.001	8	32-48	---	104

TABLE III

Results of Salt Spray Corrosion Tests on Chromium Plated FS 1020 Steel Rods

Rod No.	Cleaning Procedure	Current Density (a.s.i.)	Plate Thickness (in.)		Hours in Salt Spray		
			Standard	Periodic Reverse	First Rust	Medium Rust	Heavy Rust
5	7	2.5	.0020		2-4	6-11	11-27
6	7	2.5	.0020		6	6-11	11-27
7	7	2.5		.0016	1	2-4	6
8	7	2.5		.0015	2	2-4	6-11
38	7	2.5	.0008		1	1	2
39	7	2.5	.0013		1	1	3
40	7	2.5		.0012	1	3	4
41	7	2.5		.0007	1	2	3
14	1A	8		.0036	12-14	29-45	29-45
15	1A	8	.0032		9-11	9-11	12-14
16	1A	16		.0033	1	3	5-7
17	1A	16	.0057		16	26	26-42
18	1A	32		.0054	2	8-10	12
19	1A	32	.0041		8	11	50-66
22	1A	8	.0053		19	20	22
23	1A	8		.004	1	2-4	4-6

TABLE IV

Knoop Hardness of Chromium Plate as a Function of Applied Load

Standard Plate		Plate Applied with Periodic Reversal of Current	
Load (grams)	Hardness (Knoop)	Load (grams)	Hardness (Knoop)
200	840	200	753
400	plate cracked	400	764
500	plate cracked	500	758
		600	762
		800	745
		1000	740, 748

Note: Both plates were deposited at a current density of 8 amperes per square inch and at a temperature of 131° F.

PHOTOGRAPHS

Figure 1 - Chromium Plated WD 1045 Steel Panels After Exposure to Salt Spray. (12846-SA)

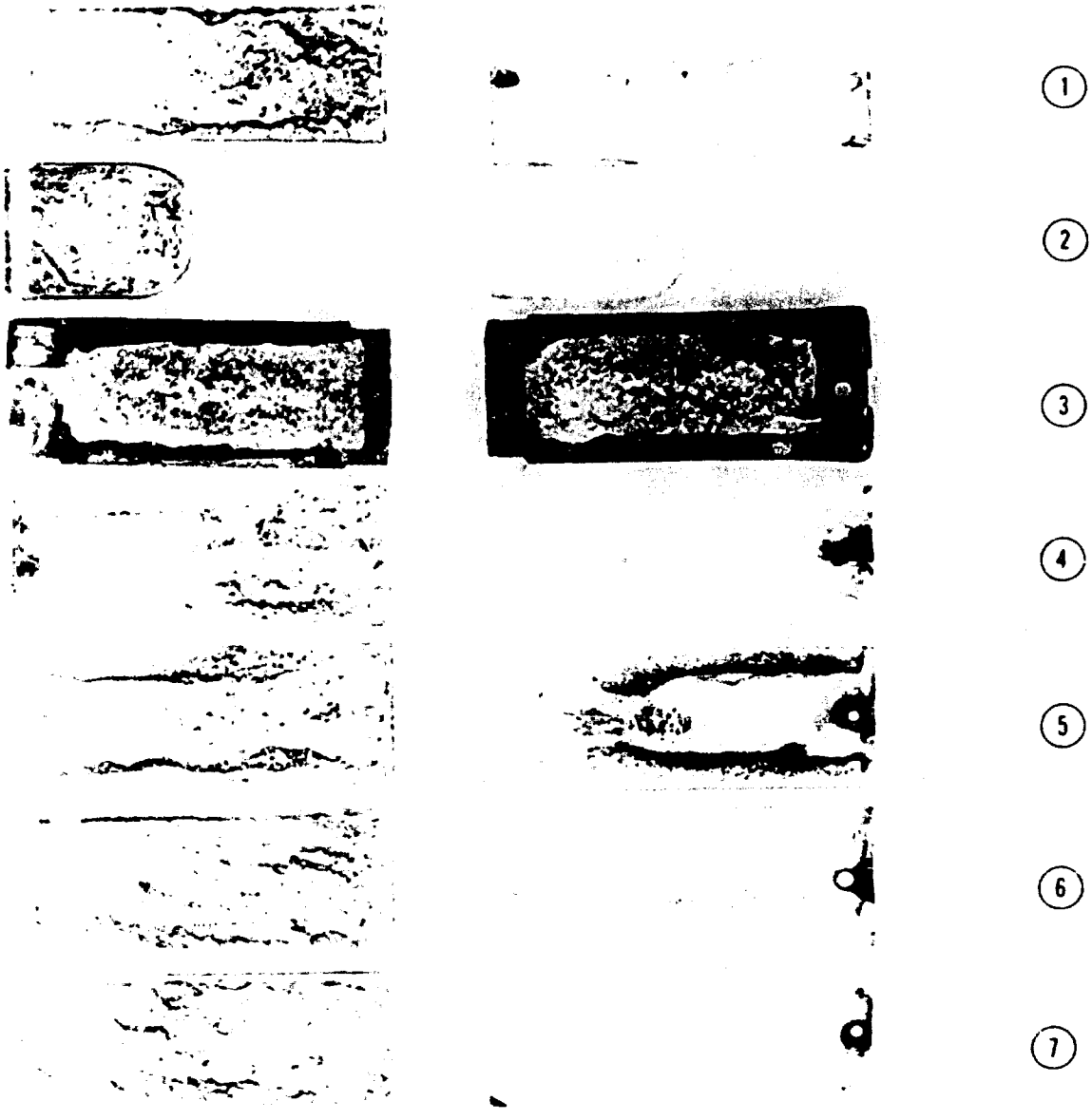
Figure 2 - Chromium Plated WD 1045 Steel Panels After Exposure to Salt Spray Showing First, Medium and Heavy Rust. (12845-SA)

APPENDIX B

Standard Procedure

Periodic Current Reversal

Pretreatment



1
2
3
4
5
6
7

12-46-SA SPRINGFIELD ARMORY - ORDNANCE CORPS 5 June 57
WD-1045 Steel Panels Plated with Chromium by Standard Procedure and with Periodic Current Reversal after Exposure to Salt Spray

Figure 1

APPENDIX B

12845-SA SPRINGFIELD ARMORY - ORDNANCE CORPS - June 1957
CHROMIUM PLATED - WD1045 STEEL PANELS AFTER EXPOSURE TO SALT SPRAY
Showing First, Medium and Heavy Rust

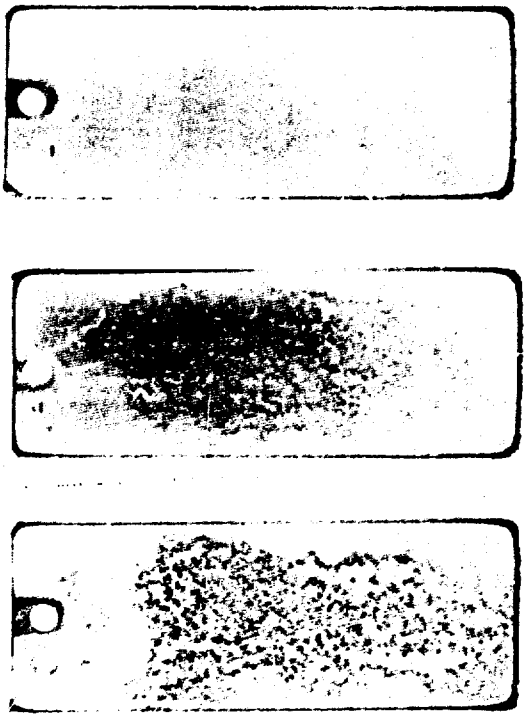


Figure 2

APPENDIX C

PHOTOMICROGRAPHS

Figure 1 - a. Plate Deposited on WD 1045 Steel By Using Periodic Current Reversal (Panel No. 171).

b. Plate Deposited on WD 1045 Steel By Standard Procedure (Panel No. 148).

Figure 2 - a. Plate Deposited on FS 1020 Steel By Using Periodic Current Reversal.

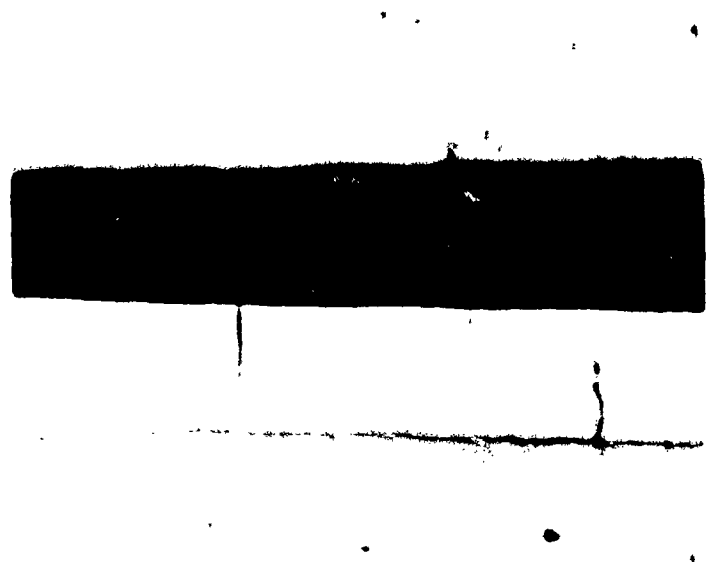
b. Plate Deposited on FS 1020 Steel By Standard Procedure.

Figure 3 - a. Plate Deposited on FS 1020 Steel By Using Periodic Current Reversal-Unetched Specimen.

b. Plate Deposited on FS 1020 Steel By Using Periodic Current Reversal-Etched Specimen.

c. Plate Deposited on FS 1020 Steel By Standard Procedure-Unetched Specimen.

d. Plate Deposited on FS 1020 Steel By Standard Procedure-Etched Specimen.



TOP: Plate deposited on WD 1045 steel with periodic current reversal, 5 seconds reverse every 3 minutes. Total time - 3 hours at current density of 2.7 a.s.i.

BOTTOM: Plate deposited on WD 1045 steel by standard procedure. Time - 2 hours at current density of 2.7 a.s.i.

Mag. 250X

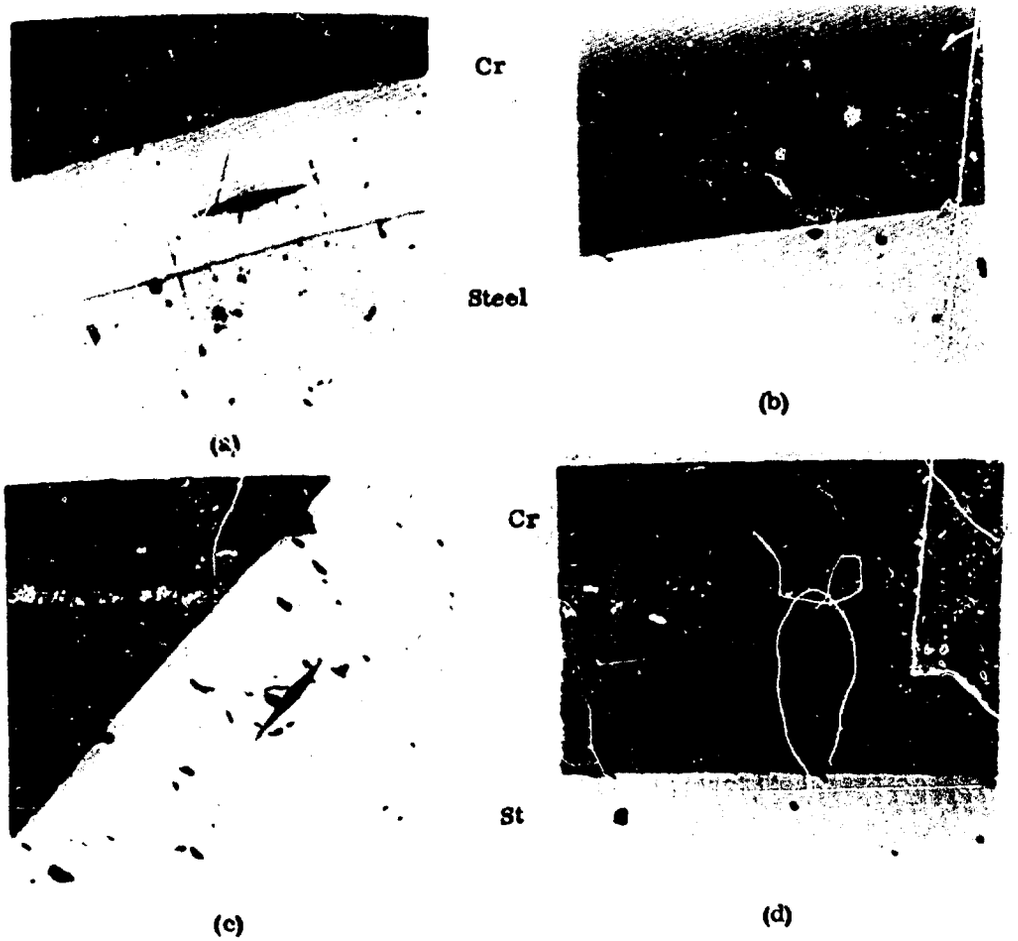
Figure 1

TOP: Plate deposited on FS 1020 steel with periodic current reversal, 3/4 second reverse, 15 second plate. Total time - 1 1/2 hours at current density of 8 a.s.i.

BOTTOM: Plate deposited on FS 1020 steel by standard procedure. Time - 1 1/2 hours at current density of 8 a.s.i.

Mag. 100X

Figure 2



TOP ROW: Plate deposited on FS 1020 steel with periodic current reversal, 3/4 second reverse, 15 second plate - total time 1 1/2 hours at current density of 8 a.s.i. - (a) unetched (b) etched 10 seconds in solution of 1-1 HCl.

BOTTOM ROW: Plate deposited on FS 1020 steel by standard procedure. Time 1 1/2 hours at current density of 8 a.s.i. (c) unetched (d) etched 10 seconds in solution of 1-1 HCl.

Mag. 250X

Figure 3